Applications of ECG Signal Analysis for R-R Complex Detection

Gabriel Ferreira Araujo
Miad Faezipour, and Abdel-Shakour Abuzneid
Department of Computer Science & Engineering
University of Bridgeport, Bridgeport, CT

Abstract

By analyzing and profiling Electrocardiogram signals, we developed a technique for detecting abnormal heartbeats of any individual accurately and focusing on RR complex timestamps. With 96% - 116% range of precision for healthy patients, abnormalities were detected and arrhythmia diagnosed with 92.43% classification rate for 1-minute period evaluation. Studies in the bioelectrical activity of the heart and beat classification methods, in general, can help diagnosing heart diseases, besides being used as early warning signs for debilitated patients.

Introduction

Electrocardiogram (ECG) measures the bioelectrical activity of the heart and has significant importance due to its automatic and non-invasive nature. In this sense, the process of human identification of arrhythmias; improper beating of the heart, whether irregular, too fast, or too slow (see Figure 1.(a) and b); and other heart problems can be troublesome as the ECG records acquired during hours or days can not be easily seen or even misclassified due to human fatigue, for example. For that reason, a wise alternative is to use computational techniques for automatic classification.

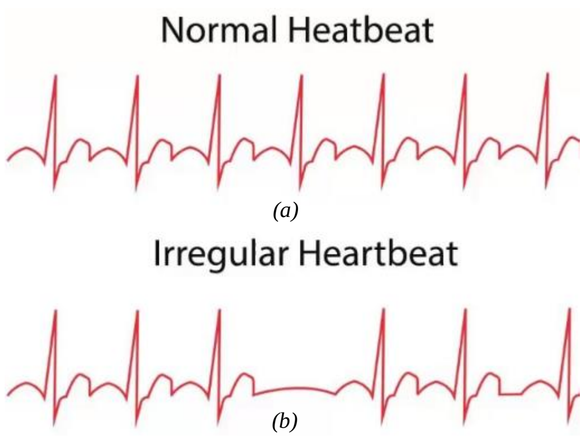


Figure 1. ECG signal waveforms for normal (a) and irregular (b) heartbeats.

During the process of classification, the MATLAB software was used as well as the PhysioBank database [1], containing complex physiologic signals (Figure 2). Literature review was also taken into consideration for the R-R complex analysis and ECG classification methods, using different software tools, mathematical methods and simulations [2],[3],[4],[5].

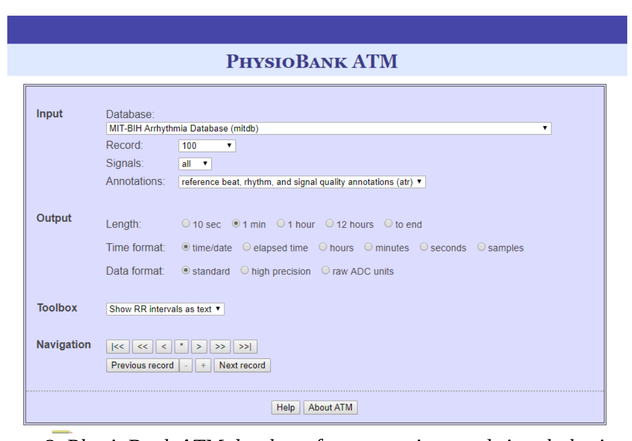
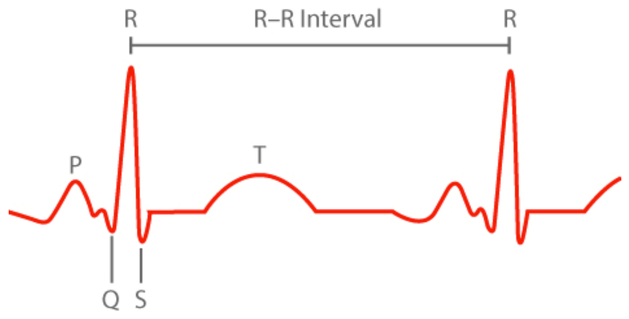


Figure 2. PhysioBank ATM database for comparison and signal plotting.

Methodology



The instantaneous heart rate of a patient can be calculated from the time between any two QRS complexes, or R-R interval. The proposed model consists of a heart rate determination and comparison along the record analyzed. For the purpose of this research, forty two (42) different ECG signals recorded using electrodes placed on the torso (MLII) were taken from the MIT/BIH arrhythmia database for the evaluation of the classifier. In the process, there was the indication of dynamic thresholds and graphic representation of R-peaks in the signal. Furthermore, the algorithm calculated the time difference average between eight consecutive peaks and compared this value throughout the record. For that, two approaches were considered: Initially, the average of the first eight timestamps was calculated and compared over the whole signal. Secondly, the sliding window approach calculated the average of all eight-pairs of beats in the signal and compared with the following beat, in sequence. Finally, if the R-R interval compared is inferior or exceeds 96% - 116% of the average [4], the patient can be diagnosed with Arrhythmia and the times of abnormality are then displayed.

Results

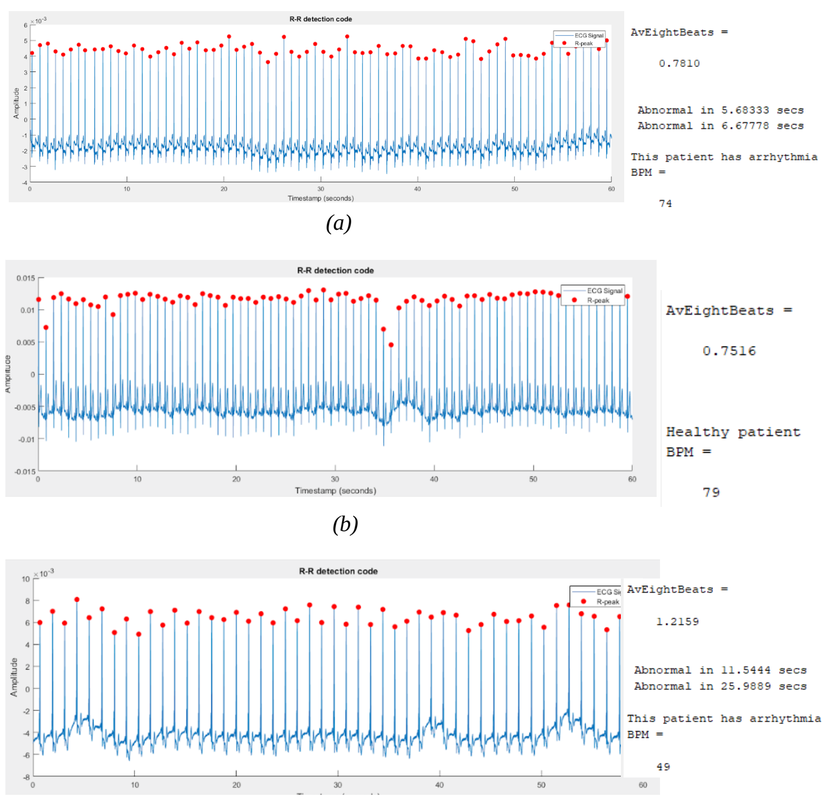


Figure 3. Results of three sample records (a), (b) and (c) of the PhysioNet database for one minute.

The classification results of our algorithm of detection yield a high accuracy of 92.43%. Figures 3.(a), (b) and (c) show three different records representation and the diagnosis for their respective patients' cardiac conditions.

Conclusion

This research introduces an efficient method of cardiac behavior detection. We have used a dataset publicly available from the PhysioNet platform; then we considered different approaches for plotting and detection, to the point that it was possible to determine abnormalities and compare with the annotated dataset. In the meantime, manual calculations and simulations were held to test the accuracy of the model. After reviewing the literature of arrhythmia detection techniques from ECG signal analysis, it also became clear that not all abnormalities refer to the R-R Intervals and that, by changing the percentage scale (96%-116%), the certainty of detection is increased. Furthermore, analyzing the signal under a sliding window perspective has been proven to have less errors and better accuracy achievements, once it refers to the person's physical condition and/or environment on the time right before the comparison.

Future research

For future direction of this work, it is possible to analyze different stages of the P-Q-R-S-T waves and align the future diagnostics with the findings of this research on the R-R interval. Another approach can be to implement the existent classification algorithm into a real time system for different individuals, analyzing the correspondent ECG signals for varying conditions, such as running, sleeping or before and after eating.

References

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